Geant4: A Beginner’s Guide Written By A Beginner

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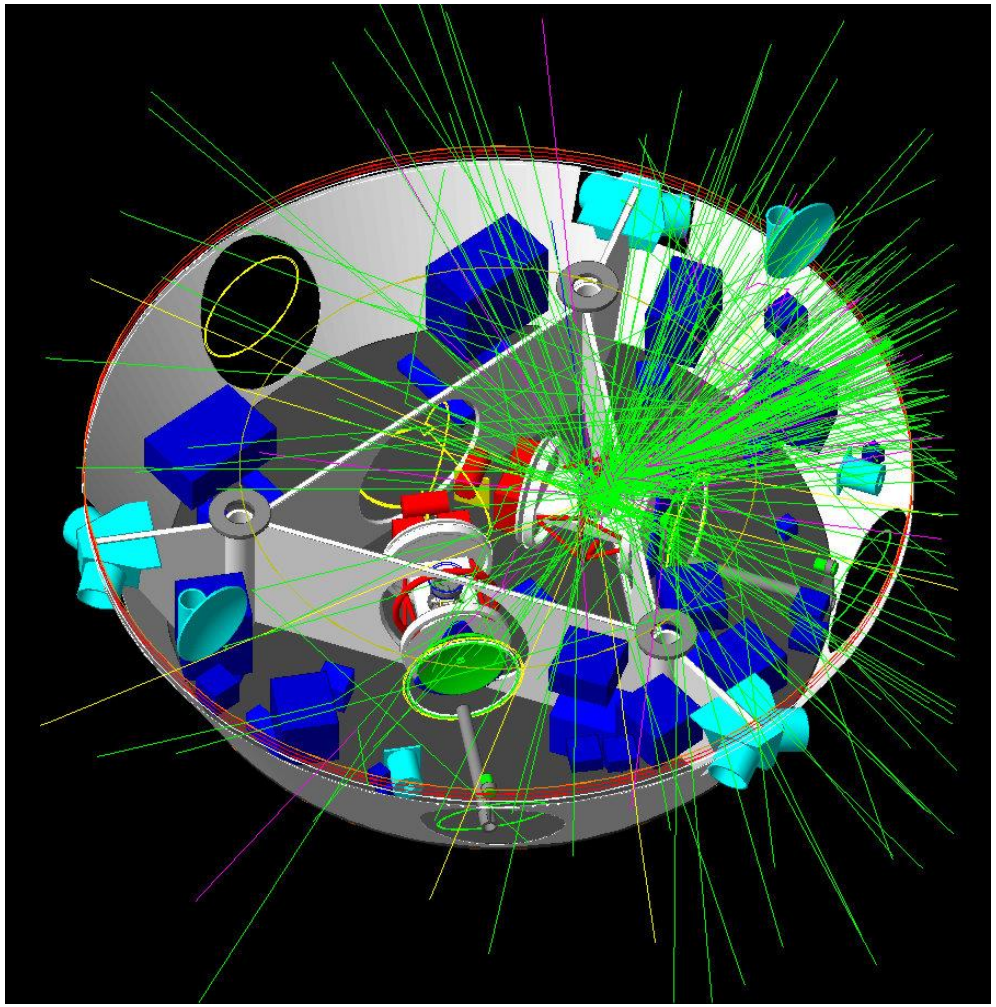
“I taught myself how to play guitar, which was a bad decision because I didn't know how to play it, so I was a shitty teacher.” – Mitch Hedberg

The Gist

- Toolkit created by CERN to simulate the passage of particles through matter.
- Designed to make the physics used transparent within the toolkit, handle a wide range of geometries, and enable an easy adaptation of different physics to fit the application.



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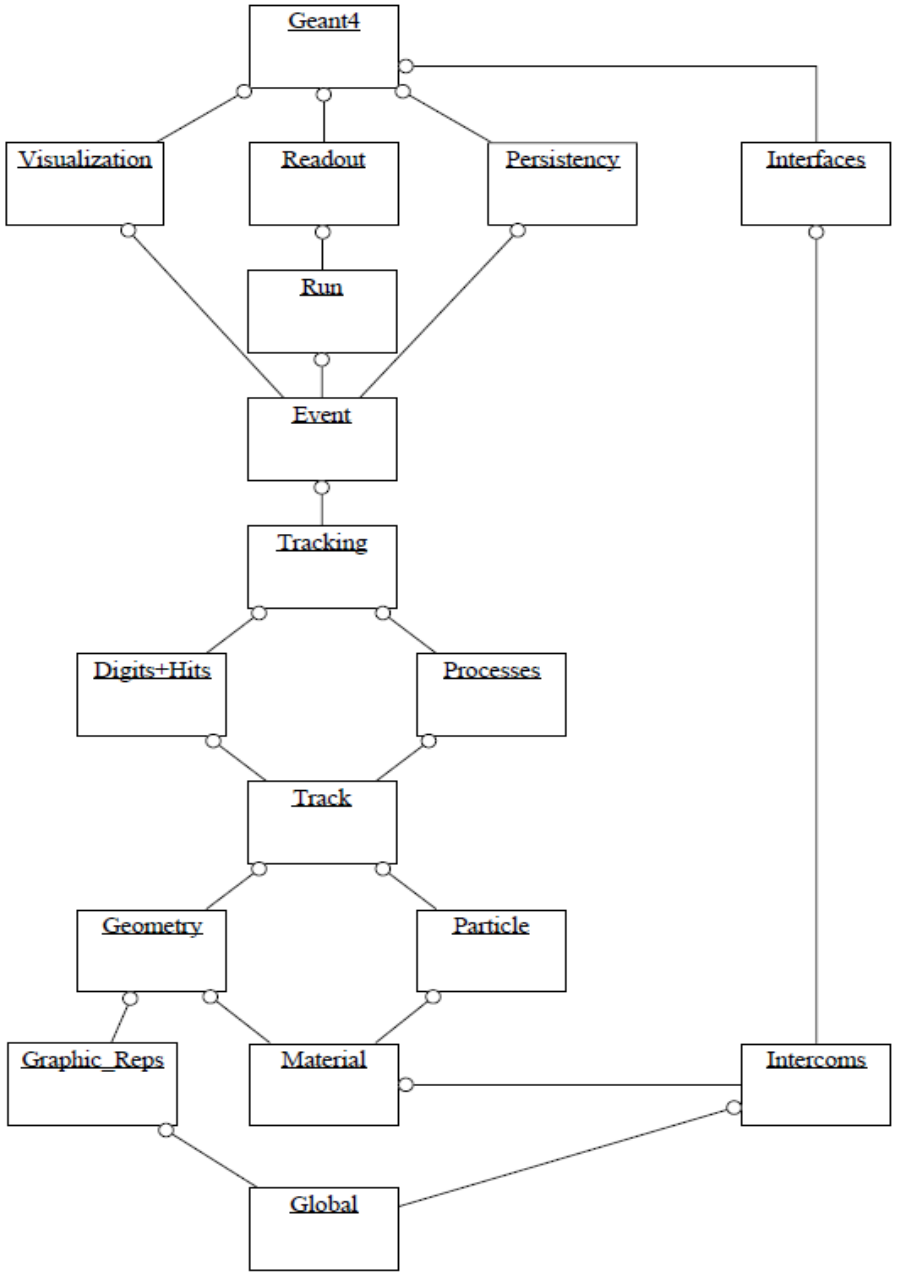


Overall Structure

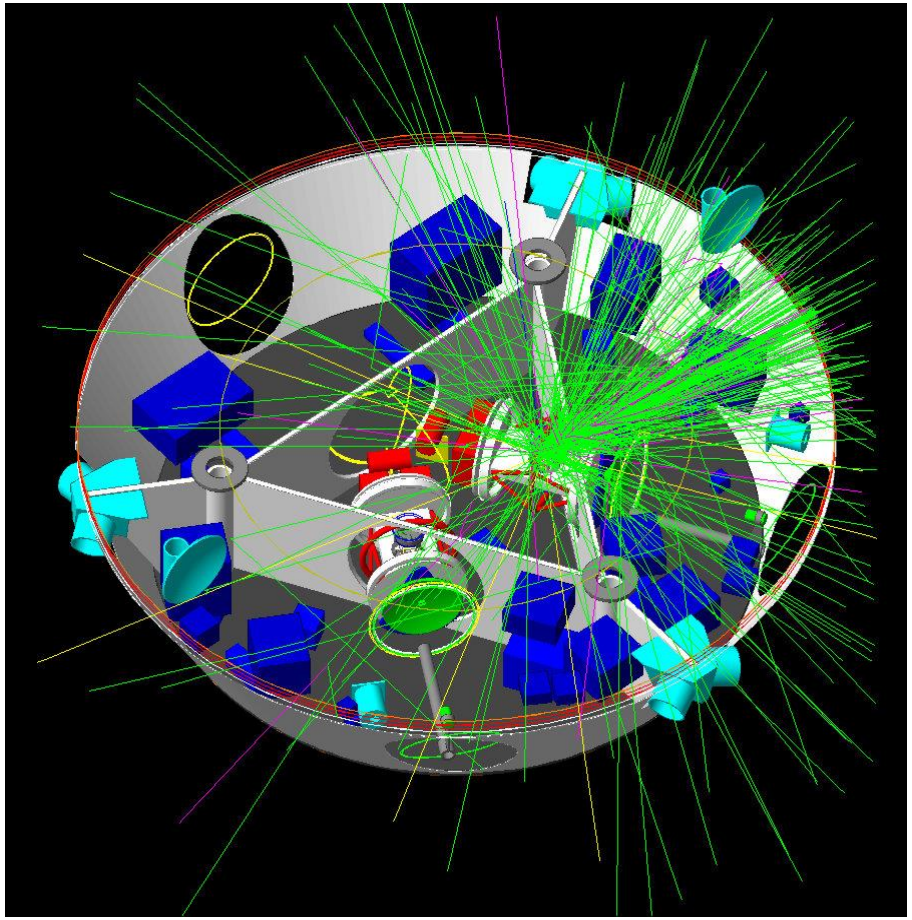
- The Top Level Category Diagram of the Geant4 toolkit.
- Geant4 is built to have no circular dependence.
- Categories at the bottom are used by virtually all higher categories.

Basic Steps to Run a Sim

- Define a Geometrical Setup
  - Material, Volume, etc.
- Define the physics involved
  - Particles, Physics Processes/Models
  - Production Thresholds
- Define the initial conditions of the events
  - Primary Track Generation
- Chose how the parameters are calculated
  - Event and Track Management
- Choose what information to save and what files to produce
- If more advanced, can also:
- Visualize Geometry, Graphical User Interface, Define own UI commands, etc.

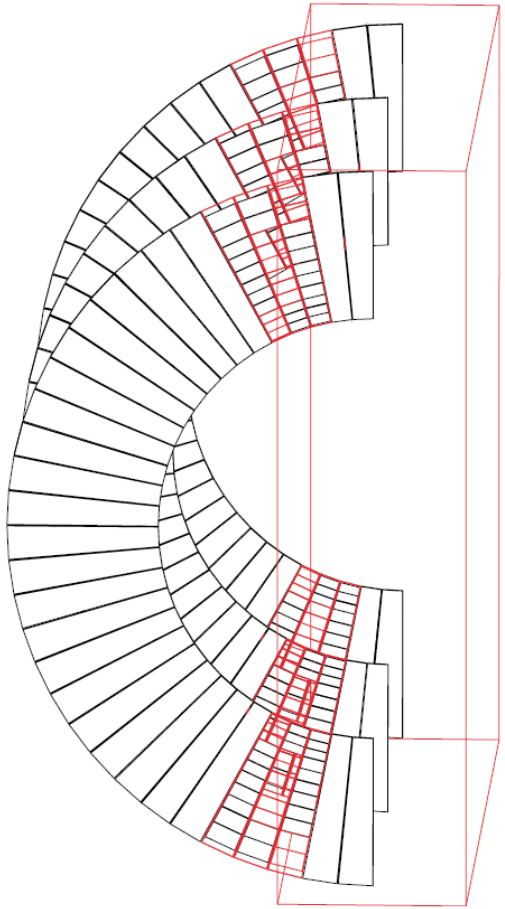
Geometry and Representation

- Now with CAD interchangeability.
- Split into **Logical** and **Physical** Volume.
- Logical:
  - Represents a detector element
  - Can hold other elements inside its volume.
  - Can define material and sensitive detector behavior.
- Physical:
  - Represents the spatial positioning of the logical volume with respect to and enclosing “mother” volume.



Geometry and Representation (cont.)

- Introduction of Solids using the concept of Constructive Solid Geometry (CGS).
- More complex solids are defined by their bounded surfaces and belong to Boundary Representations (BREPs).
- Geant4 provides multiple packages (DAWNFILE, DAVID) that can be used for geometry verification.
  - Checks that volumes do not overlap with one another.
  - Checks that the “daughter” volumes are fully contained within the “mother” volume.



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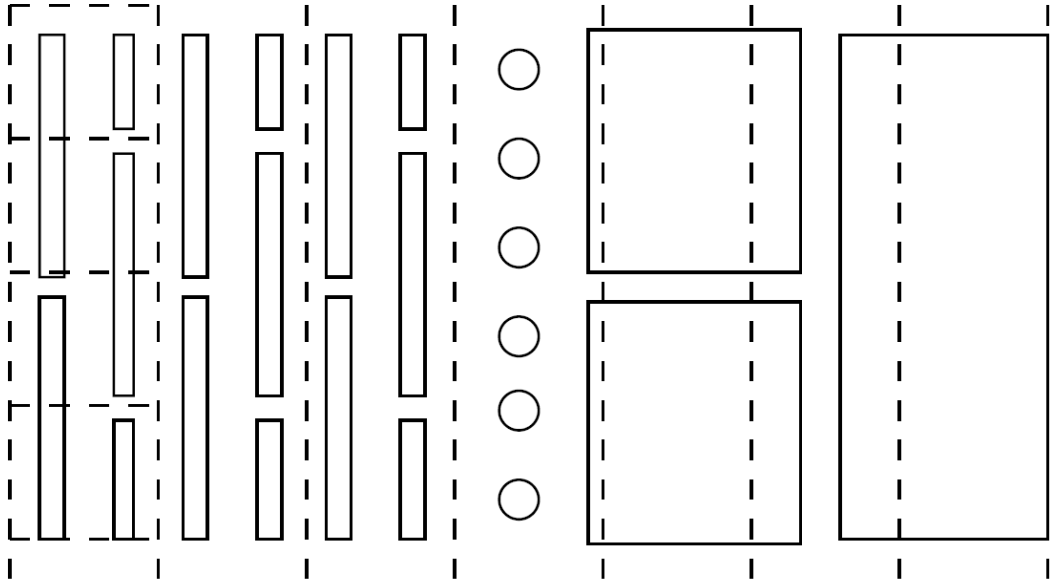
Particle Interaction in Matter

- Drives tracking activities through three possible tracking outcomes:
  - At Rest – Particle….at rest.
  - Along Step – Implements Energy Loss or Secondary Particle Production happening continuously through particles trajectory.
  - Post Step – Invoked at the end of a step (e.g. secondary particle production via a decay or interaction).
- Geant4 uses predefined packages and public evaluated databases for the physical processes used in the simulation. (Can be changed by user).
  - Ex: G4(e/h)Ionisation, G4eBremsstrahlung, etc.
- A physics process may aggregate various components, each one being represented by a model; models can play complementary or alternative roles.
- Materials category reflects nature: made of single or mixture of elements, elements made of single of mixture of isotopes, etc.

Tracking Management

- Particles are moved in steps by physics processes or by detector geometry.
- After a step a track's state records whether it is on a boundary, whether it is exiting the current volume, etc.
- Event Handling has three stacks: "urgent", "waiting" and "postpone to next event".



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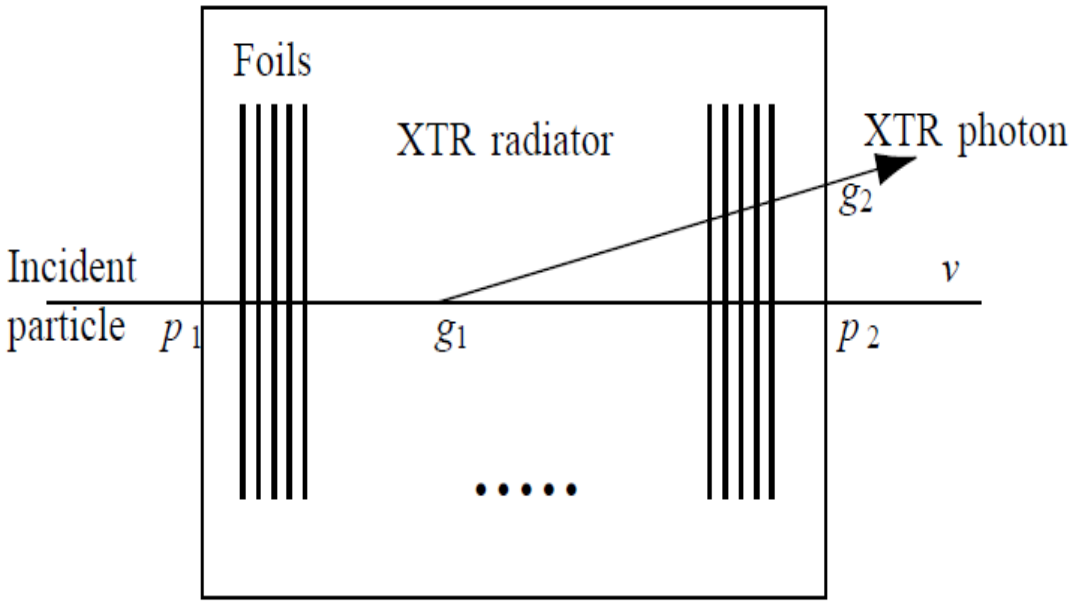
Event Management

- Provides an abstract interface to external physics event generators for the generation of the primary particles which define a physics event.
- G4Event class:
  - Contains PV and PP.
  - Stores hits and digitization
  - Stores trajectories for “simulation truth”



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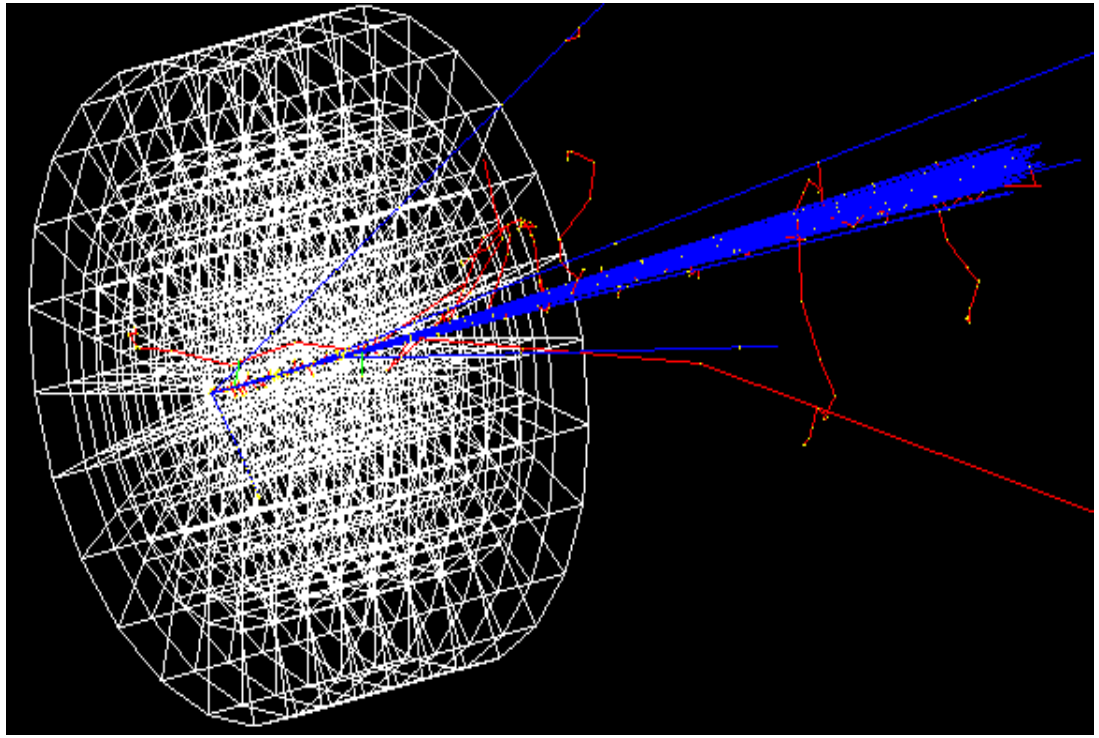
Digitization and Hit Management

- Hit – a snapshot of a physical interaction
- Digit – Actual Detector output (e.g. ADC/TDC count, etc.)
- Logical Volume can point to a “sensitive detector”
- Sensitive Detector creates hits based on the user’s implementation of the detector response.



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User Interface

- Intercoms – provides command definition and interpretation tools.
- Interfaces – provides graphical and non-graphical “sessions”.
- Interfaces also implement an expandable command interpreter which is the key mechanism in Geant4 for realising customizable and state-dependent user interactions with all categories without being perturbed by the dependencies among classes.

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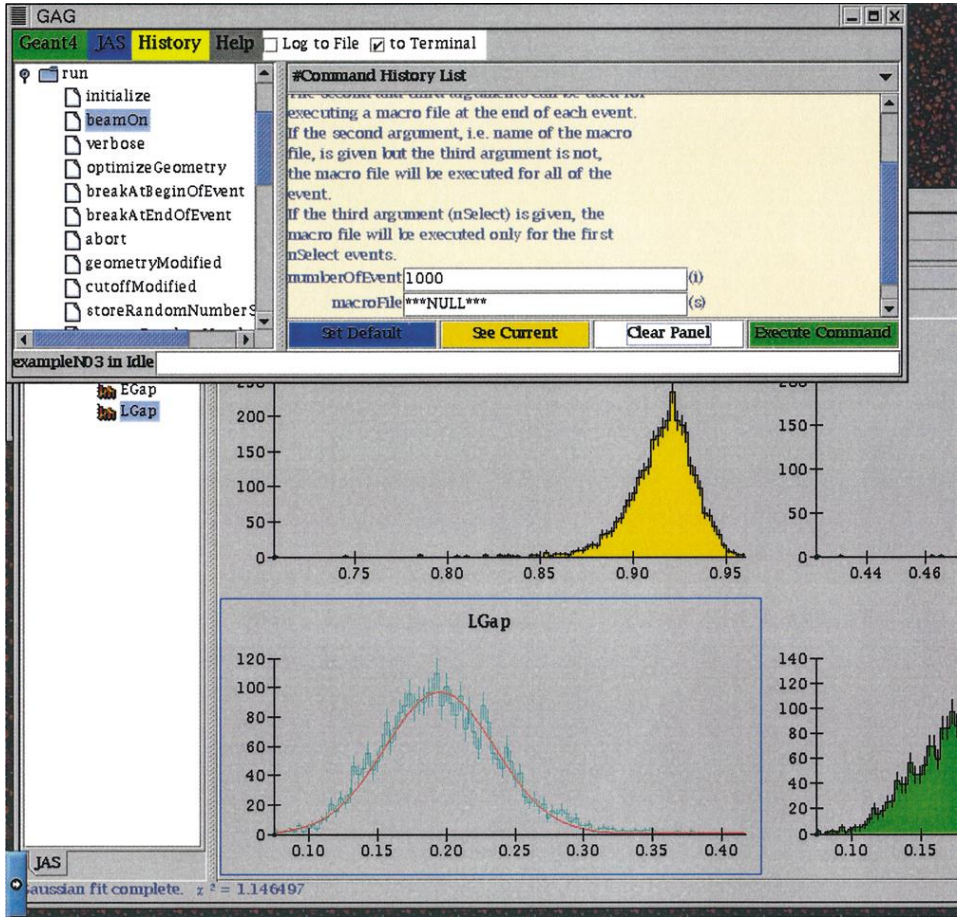

Visualization and Visualization Framework

- To visualize the detector geometry, particle trajectories, tracking steps, etc.
- Graphics System – An application running independently alongside GEANT4 or a graphics library to be compiled with GEANT4.
- Visualization Driver – Concrete implementation of an interface. Can use a graphics library, communicate with an independent process, or write an intermediate file for a separate viewer.

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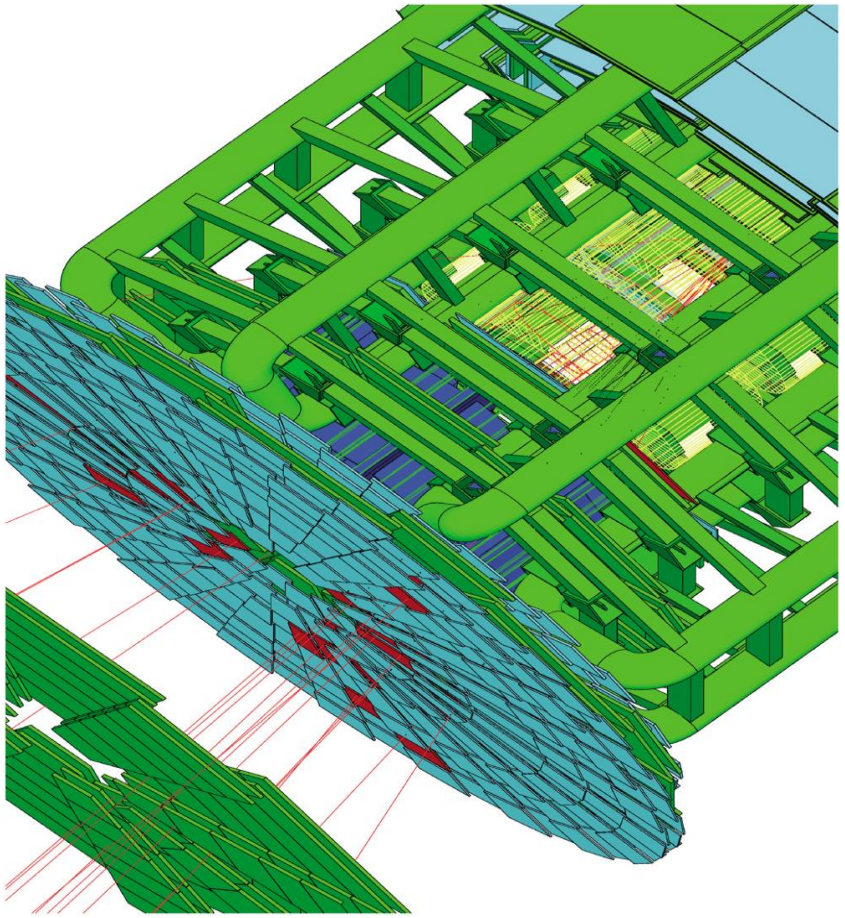
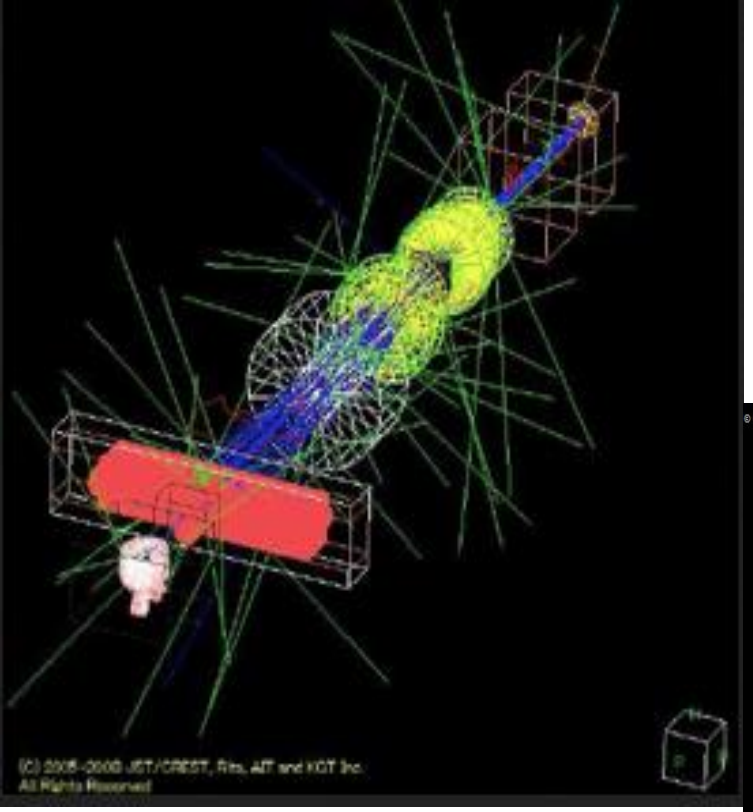


Applications

- **Hadronic Physics**: String Models, Intranuclear Cascade Models, precompound, Fermi-Breakup, Fission/Evaporation, Radioactive Decays
- **HEP**: BaBar, CMS, LHC. First use of Geant 4 for an actual Physics Experiment.
- **Space Applications**: Planetary Scale Simulation of Soil Level, Spaceship Sim for Radioprotection, etc.
- **Medical**: Brachytherapy Devices, Radioprotection, Nuclear Imaging, etc.
- **DNA Scale Sims**: Applied to Silicon for Single Upset Events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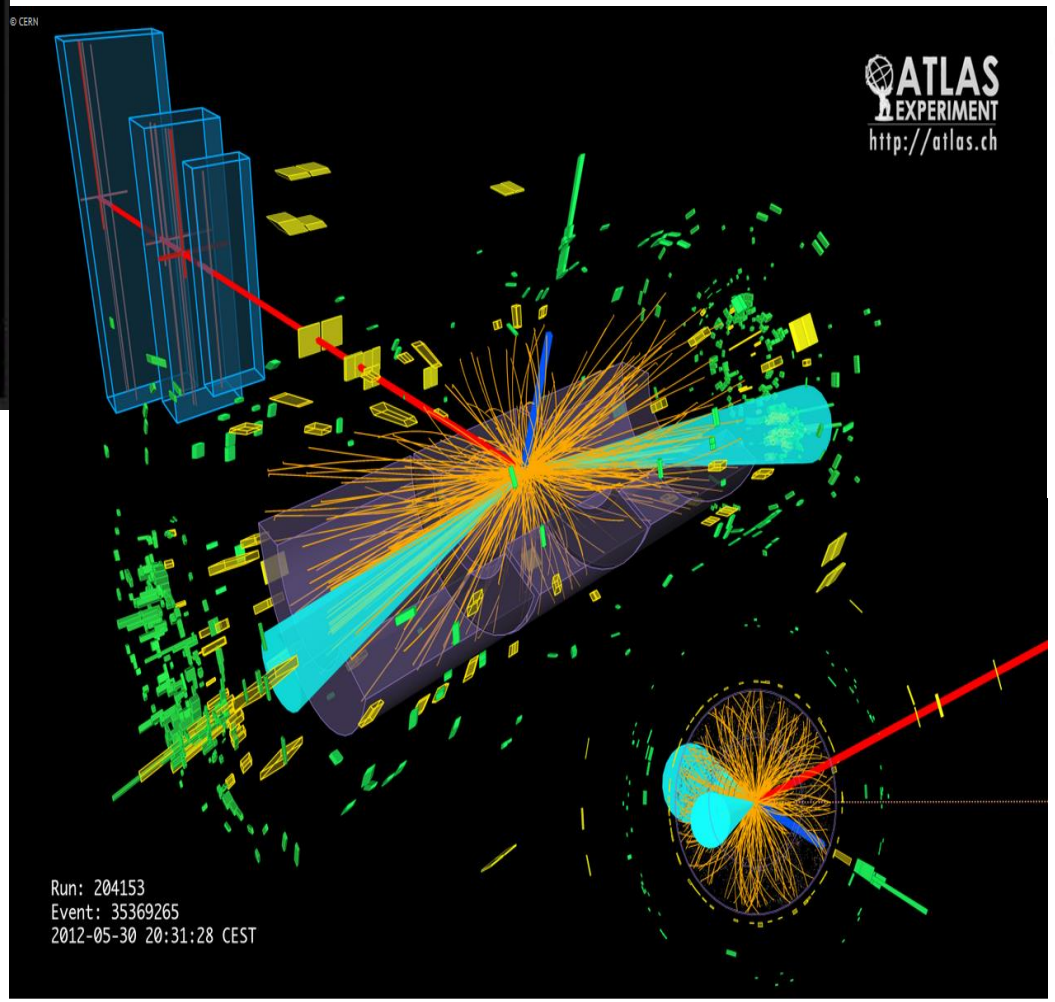
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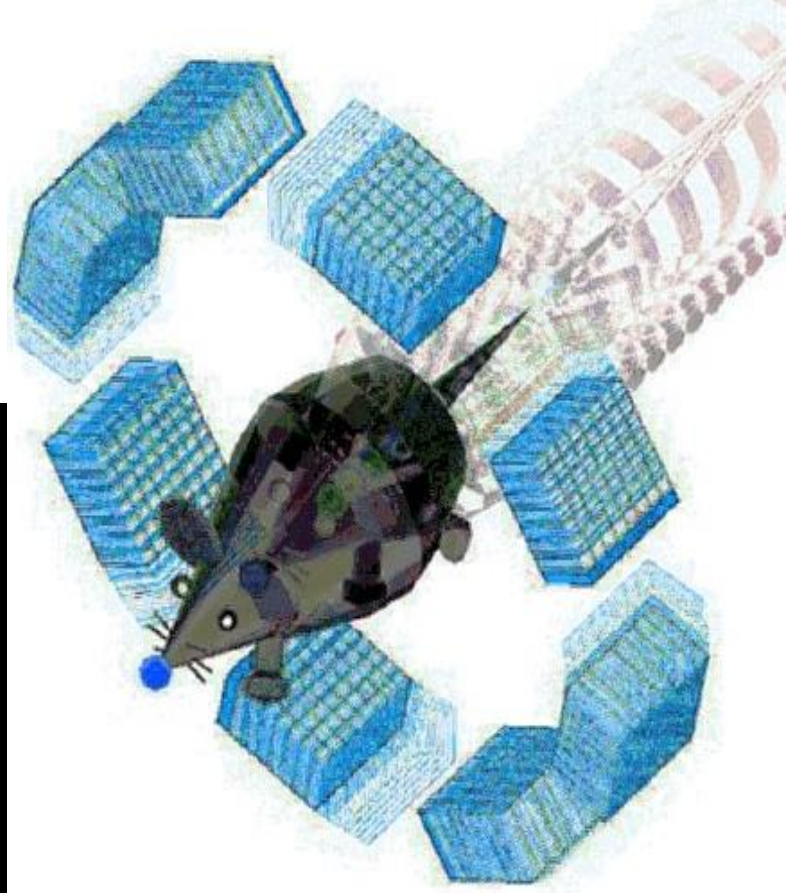

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References

- [1] - http://geant4.web.cern.ch/geant4/gallery/fullsize/LISAEvent.jpg
- [2] – S. Angostinelli et al., "*Geant4 – a simulation toolkit",* Nuclear Instruments and Methods in Physics Research A 506 (2003) 250–303
- [3] – http://hypernews.slac.stanford.edu/HyperNews/geant4/get/AUX/2015/03/24/04.42-57847-02_03_15.png
- [4] – http://www2.kek.jp/proffice/archives/feature/2010/images/Geant4_4.jpg
- [5] – R.M. Bianchi, "*Event display of a 2-tau candidate in the ATLAS detector*", http://cds.cern.ch/record/1631395
- [6] – S. Jan et al., "*Geant4 Application for Emission Tomography: a simulation toolkit for PET and SPECT*", http://wiki.opengatecollaboration.org/images/d/d7/GoldGate.jpg